# National Measurement Institute, Australia
# Report on Research and Development Activities in Electricity and Magnetism
# CCEM Meeting, March 2019

## *LOW FREQUENCY*

### *Measurement of magnitude and phase of harmonics in distorted signals with a Josephson Arbitrary Waveform Synthesizer*

NMIA has developed a system to provide traceability for the magnitude and the phase of harmonics of distorted signals (voltage and current) to a Josephson arbitrary waveform synthesizer (JAWS). The new systems covers the voltage range from 0.01 V to 240 V, current from 0.005 A to 20 A, and phase from -180° to +180°. The magnitude uncertainty ranges from 0.001% to 0.005% and the phase angle from 0.0016° to 0.010°, depending on the harmonic number and harmonic magnitude. The calibration setup is based on two NIST Josephson junction arrays and microwave circuit designs, the NMIA inductive voltage divider, and the NMIA multi-range current transformer and current shunts. The new system extends the existing NMIA's capability of the magnitude of the harmonics that is traceable to electrical power using the thermal power comparator.

### *Extension of the voltage range of a Josephson Arbitrary Waveform Synthesizer to 120 V*

We have developed a system to extend, by a factor of up to 1000, the voltage range over which Josephson arbitrary waveform synthesizers (JAWS) can be used in ac voltage metrology. The system is based on the NMIA precision inductive voltage divider and a NIST JAWS system using a lock-in amplifier as the detector. Using a JAWS with a maximum output voltage of 250 mV (rms), we made accurate voltage measurements up to 120 V at 60 Hz with expanded uncertainties ($k$=2.0) of no more than 1.5 µV/V and demonstrate that the system can operate up to 1 kHz.

### *High-Frequency Power*

NMIA has been collaborating with NIM China on an ac power standard up to 100 kHz. At NMIA, the electrical power standard has been established, using a Thermal Power Comparator to relate the alternating power to that of known dc signals at frequencies up to 200 kHz. At NIM, the national power standard has also been established at voltages up to at frequencies up 100 kHz. NMIA hosted two three-month visits by Dr Xianlin Pan from NIM. During this time, a comprehensive comparison between the NMIA and NIM approaches to the scaling of ac current and ac voltage up to 100 kHz was completed. The comparisons show excellent agreement between these very different techniques and instil confidence in the measurement of electric al energy up to 100 kHz at both institutes.

## *IMPEDANCE*

### *Calculable capacitor and precision four-port ac capacitance bridge*

A new calculable capacitor and associated impedance measurement chain is being built at the NMIA. All components in the chain will be configured as four-port devices and measured at frequencies from 199 Hz to 1990 Hz.

The final assembly of the calculable capacitor has been completed very recently. The implementation of the interferometry system has presented some challenges. It is hoped

that the noise that is currently limiting its operation will be largely eliminated once the capacitor is evacuated.

Many elements of the precision four-port capacitance ratio bridge are complete or nearing completion. The source and ratio transformers are complete, as are the active coaxers, the low-noise preamplifier and the two sets of reference capacitors with values from 5 pF to 500 pF. The quad power amplifier is progressing and the programmable injector/detectors, the quadrature source, the balancing IVD and the air bath are all close to completion. Ongoing collaboration with NIM is assisting with this work. This year Drs Yan Yang and Huang Lu will visit NMIA in June to progress aspects of this work.

Calibration of the main ratio transformer will be achieved using a new four-port calibration facility based on Thompson's method. The calibration (or "bootstrap") transformer is complete. Dr Carlos Sanchez of NRC is completing the zero-admittance voltage comparator and the calibration signal transformer.

The assistance and support of NIM and NRC are gratefully acknowledged.

## *HIGH VOLTAGE*

### *A new Design of 150 kV Precision DC Voltage Divider*

A new design of the150 kV DC voltage divider using molded shielding shells for resistor elements has been developed and tested. The new shielding shells are of molded ABS plastic plated with nickel. They are used to replace the previously used aluminum shielding shells. The new design reduces the total mass of the divider and also allows faster construction of the divider. The new design offers the same stability of the voltage ratio as the old design, which is typically less than 10 ppm at voltages up to 150 kV.

### *System for the calibration of Voltage Transformers*

NMIA has completed a new digital voltage transformer calibration system. The new system uses two digital multi-meters, a compressed gas high-voltage capacitor and an NMI developed software package. The new systems offers similar uncertainties as the existing systems, but with increased calibration efficiency and lighter weight for on-site calibrations.

### *New measurement system for insulator impulse puncture tests*

A new measurement system was developed for performing insulator impulse puncture tests according to IEC 61211. The system includes a NMI-built high-voltage fast impulse divider, a fast commercial digitiser and an NMI developed software package. A comparison between NMIA and VTT Finland was performed, achieving good agreements for a rise time down to 150 ns at 300 kV level.

Enquiries: ilya.budovsky@measurement.gov.au